AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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(Vol. XI.—December, 1882.)

DISCUSSION

By JAMES P. ALLEN, Jun. Am. Soc. C. E., ON PAPER CCXLIX.

RAPID METHODS IN TOPOGRAPHICAL SURVEYING.

JAMES P. ALLEN.—I am satisfied that Mr. Dawson's conclusion as to the best single instrument for a survey of this character would be fully established by experiment.

An ordinary stadia transit or theodolite, with a good self-reading rod, is equal to all of the duty required upon the survey which he describes. The preference is usually given to two stadia hairs, equally or about equally spaced above and below the ordinary horizontal hair of the instrument. These hairs should cover about one foot on the rod for each 100 feet of distance. They may be fixed upon the same diaphragm as the ordinary cross-hairs, or they may be made adjustable. Either plan has advantages as well as disadvantages.

Long distances can be read on a rod of the ordinary length by taking first the space on the rod covered by the middle and upper hair, and

afterwards that between the middle and lower hair. The sum of these will be the total space or stadia reading.

With a rod of 14 feet we are thus able to read 2 800 feet, than which longer sights will rarely occur in practice. There is a somewhat lower practical limit to the distance, which can be read with a self-reading rod, due to the difficulty of distinguishing the figures, except under favorable conditions.

With a clear atmosphere and the sun shining upon the rod, it is quite possible to read 2 500 feet. 2 000 feet might be assigned as a practical limit with the ordinary American transit. It is frequently possible to double this distance between stations, or turning points, by measuring from both stations to a point about midway between them on the line; or this point may be taken slightly to one side, and its direction from the stations observed as well as the distance. The direction from station to station is also observed at the first setting.

The self-reading rod is generally preferable, on account of the greater rapidity in its use, and also because with it a skilled assistant is not necessary. It is probably quite as accurate for a survey of any extent, the errors balancing each other.

A skillful observer can read the distance upon a self-reading rod held on a boat, provided the motion of the boat be not too great.

The rod is adjusted to the instrument, in the case of fixed hairs, by measuring a base, determining the length of rod covered by the stadia hairs upon this base, and dividing this into spaces representing 100 feet each. A stencil is then made of the desired pattern and the rod marked for its whole length. With adjustable hairs the rod is prepared first; a base is then measured, and the hairs adjusted to read the corresponding distance on the rod.

The plan followed by Mr. Dawson of measuring his base from the anterior focus instead of the centre of the instrument seems to be a good one. The error, which appears in all stadia distances, thus becomes constant, and a constant additive correction must be made to each reading. The rod cannot be so graduated as to correct this error entirely. In fact, the plan which Mr. Dawson used does not correct it except for horizontal readings. However, for readings out of level a very simple formula of reduction may be used without appreciable error.

With a self-reading rod the use of tables is obviously unnecessary, except for reduction to the horizontal and for heights. The horizontal dis-

tances and the vertical heights can be obtained by tables or by diagrams; or, if there are only a few points, they may be calculated directly.

Very accurate leveling can be done, provided there be a level under the telescope, as is generally the case. If the stadia hairs are adjustable, the self-reading rod may be laid off into feet, tenths and hundredths, and becomes a correct level-rod at once. Otherwise a correction must be applied to all heights.

This method of surveying is valuable on account of its economy. Good preliminary surveys may be made where the funds available would not warrant the expense of regular methods.

It appears to be especially useful in hydrographical surveying. Here the lines of sight are generally horizontal, making corrections unnecessary; cutting can be avoided by judicious management, as noted by Mr. Dawson, and a complete instrumental survey made at a minimum of expense.

As a method it cannot be classed in point of accuracy with chain surveying or triangulation. But, since it is susceptible of a higher degree of accuracy than is usually attained in public surveys, with fewer men and generally in less time, it seems well suited to American engineering practice, when there is a constant demand for rapid and economical methods.

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CCL.

(Vol. XI.—December, 1882.)

WEIGHTS AND MEASURES.

By FRED. BROOKS, Jun. Am. Soc. C. E.

READ JUNE 18TH, 1881.

WITH DISCUSSION

By JACOB M. CLARK, M. Am. Soc. C. E.

It is a common remark that in regard to metrology, harmony of action between the United States and Great Britain would be very desirable, on account, firstly, of the magnitude of the commercial and other intercourse between the two countries, and secondly, the correspondence already existing between their weights and measures. This opinion was expressed in several of the reports made about three years ago by the department and bureau officers of the United States Government in reply to a resolution of the House of Representatives which drew out their opinions upon metrological reform. There would be more force in the suggestion if past experience encouraged us to hope for any united action; there is certainly reason in it, for it recognizes the importance of taking foreign nations into consideration; both of the assertions upon which it is based require to be scrutinized.

(1.) I will first present the facts as to whence the imports into the United States come ; for the next step in her metrological legislation is likely to relate to the business of the custom houses. The present enormous development of international commerce is chiefly the growth of the present century, and is due to the introduction of railroads and steamships to facilitate transportation, to the successive removals since the end of the Napoleonic wars of many restrictions upon trade, to the increase of metallic currency by the discovery of gold in California and Australia, and to other causes. It is only comparatively recently, therefore, that the reasons for requiring international uniformity in weights and measures have been nearly as plainly recognized as those for requiring uniformity throughout any one nation. The official reports from the Bureau of Statistics of the U. S. Treasury Department show that during the year ended 30th June, 1879, the value of merchandise imported into the United States was $445 777 775, of which 28 per cent. was produced in Great Britain and other countries which use her imperial weights and measures ; 59 per cent. was produced in countries that have adopted within the last hundred years a common international system of weights and measures, and the remaining 13 per cent. was produced in countries which use various other weights and measures ; all of which is exhibited in detail on the accompanying diagram (Plate XXXIV.).

(2.) Now let us look at the second assertion, about an existing correspondence between the weights and measures of Great Britain and those of the United States. In the United States we have for one measure of length the vara,* by which, under the laws of Texas, the public lands of Texas are surveyed and described. For one measure of surface we have the arpent,† by which real estate is advertised and sold in the Mississippi Valley, according to the report made by the Commissioner of Patents among those mentioned above. For capacity we have incongruous measures for liquid and dry substances, and a great deal of variety in the laws of the different States about them, as is stated with considerable detail in an addendum to the report made by the Commissioner of Education among those mentioned above. For instance, a

* I am credibly informed that the arroba, the fanega, and other weights and measures of Spanish origin are also in use in Texas. August 24, 1881.

Trautwine's Engineers' Pocket Book (15th thousand, 1881) gives the vara and the legua as having legal values in California, the values being a little greater there than elsewhere.

† The map of Montreal which is now hanging upon the wall of this hall has a linear scale of arpents.

gallon of milk in Vermont and Massachusetts is 231 cubic inches; in New Hampshire 282 cubic inches. The bushel, though usually understood to be a capacity measure, is for many substances defined to mean a weight; the bushel of oats and the bushel of barley have each six or eight different values, and for various products in the several States and Territories the legal bushel has forty different weights; 1 000 bushels of barley, bought in the State of Kansas at 48 pounds to the bushel, would become 1 500 bushels in New Orleans, where a contract for delivery would, in the absence of agreement to the contrary, be satisfied at the rate of 32 pounds to the bushel. In the case of rye, 1 000 bushels would, by the same transfer, become 1 750 bushels. In Indiana a bushel of coal mined in the State is fixed at 70 pounds, but a bushel of coal mined outside of the State and sold within the State must contain 80 pounds!

As for weights proper, the United States standard pound, preserved at the Mint at Philadelphia, is a troy pound, and is the only material weight or measure that has been declared to be a standard by Act of Congress. Diamonds and other precious stones are sold by the carat, an anomalous weight, of which conflicting definitions may be found. One hundred pounds have been made a hundredweight, and 2 000 a ton, in Massachusetts since 1826; and probably some other States have passed similar laws; I did not suppose Pennsylvania was among them. Our fellow member, Mr. Coleman Sellers, of Philadelphia, stated, however, in his very interesting address to the Mechanical Engineers, last fall, that a ton of 2 000 pounds is used in machine shop practice and in selling machinery.

Now, in England the above described United States units *are not within the pale of the law.* The Weights and Measures Act, 1878, which went into effect in the United Kingdom January 1st, 1879, is chiefly a consolidation of the statutes previously existing, and had for one of its principal objects to extirpate the various irregular weights and measures, which to an extent hardly credible have been customary and local standards in England. This Act well illustrates the importance which is justly attached to having uniformity established throughout the country, and also the method by which it is secured. Contracts by weight or measure are declared void unless they are according to the weights and measures authorized by the Act.

I will quote a single section :

"24. Every person who uses or has in his possession for use for trade a weight or measure which is not of the denomination of some Board of Trade standard, shall be liable to a fine not exceeding five pounds, or in the case of a second offense ten pounds, and the weight or measure shall be liable to be forfeited."

The troy pound is not a Board of Trade standard. The imperial gallon and bushel for both liquid and dry substances hold respectively 10 and 80 pounds of water ; they were introduced into England more than 50 years ago, and into Canada, I believe, within the last decade ; they are entirely independent of the measures which go by the same names in the United States. The imperial hundredweight is defined as 8 stones, and the stone as 14 pounds ; and decimal standards of imperial weights are not adopted by the Board of Trade except for the smaller denominations like ounces and grains. Decimal subdivisions are permitted to be used, however, in expressing weights and measures in contracts.

As an illustration of the practice in this respect, take the 19 cwts., 5 stones, 6 pounds, 9 ounces, 15.04 drams, given in a schedule to the Act as the imperial equivalent of the millier (or 1 000 kilos used by the rest of the world, and authorized by this Act to be used as a term in British contracts). The similar equivalent given in the United States law of 1866 is 2 204.6 pounds. With difficulty do we recognize that the two expressions are of the same magnitude. There is a little less contrast in the equivalents of measures of length ; the first item in the British schedule is 6 miles, 376 yards, 0 feet, 11.9 inches ; in the United States schedule, 6.2137 miles. Some of our citizens who happen to remember how many yards make a mile, etc., and who are good at figures, can ascertain by computation that these are practically the same length.

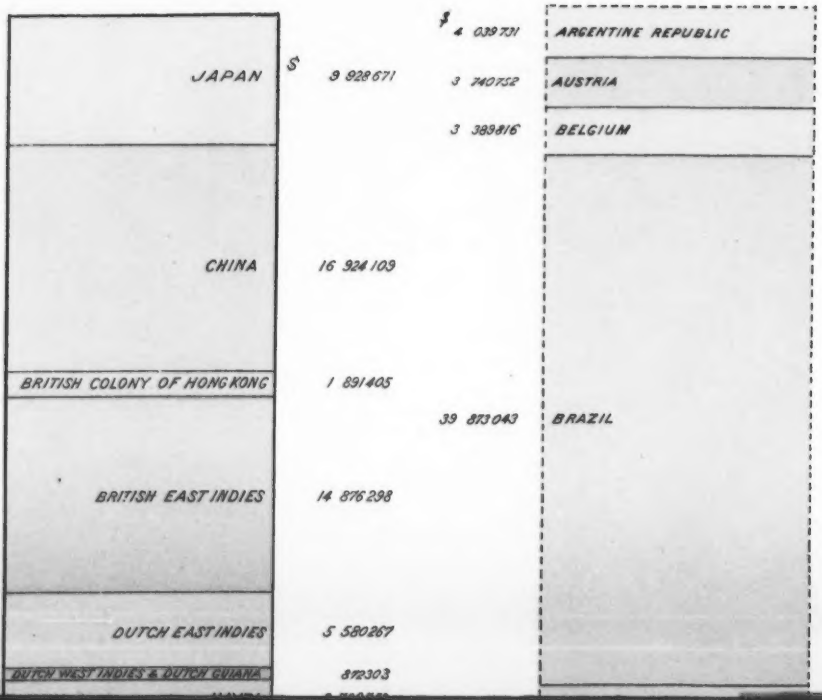
I will close by observing that one cause among others of the annoying diversities which we have been viewing, is the disposition of particular professions or trades to adopt what seems to them good, regardless of the rest of the community. Most of us see our neighbors' faults more clearly than our own ; so let us look for a moment with abhorrence upon the carats of the jeweler, and the scruples, fluid ounces, and other mysterious quantities of the apothecary, and make up our minds that weights and measures so discordant with what are generally used ought not to be allowed. Then let us humbly reflect upon what the jeweler and apothecary would say of Gunter's chains and links, and the railroad en-

gineer's tenths and hundredths of a foot. Shall an amount of irregularity greater than is tolerated by old England be submitted to indefinitely by her progressive children on this side of the Atlantic? Of course not. It is generally agreed that the existing metrology of the United States must be reformed. Our physicians and druggists have already taken effective action looking to the abandonment of their ancient apothecaries' table. Civil engineers cannot be indifferent to the importance of the subject, unless they are willing that their profession shall lose that influential position in the community which breadth of view and public-spirited action entitles it to hold.

DISCUSSION.

Jacob M. Clark, M. Am. Soc. C. E.—There appears to be some misapprehension both as to the present status of the French system and its inherent merits. The argument drawn from the present aspect of commerce, so far as it applies, is of undoubted weight. But it should be observed that the same or kindred arguments may be, and always have been, used to perpetuate errors, until resulting evils become entailed, or else have to be displaced by the force of public opinion.

Where the French system has been made compulsory, it seems to have been done without much regard to the wish or convenience of the people; and where its use has been made permissive, there are formidable tendencies against it. Many who were at first attracted by its alleged scientific foundation and systematic decimalization have had their views modified by maturer thought. It is an itinerary, founded on the earth's circumference, not novel in principle; with no better division of the circle than ancient analogous systems, a palpable error in its unitary meter, and inferior to them in that it presents no convenient manual unit. On this latter point, the experience of men, as expressed in their systems, is a more cogent and conclusive fact, at least to a philanthropist, than any superinduced state of commerce can possibly be. The manual unit for general purposes, whenever founded upon convenience, has always ranged between 17 and 30 inches. The foot, with duodecimal subdivision, has been largely used by builders on account of its convenience for fractional subdivisions; but the manual implement has


JAPAN
9 928 671
CHINA
16 924 109
BRITISH COLONY OF HONGKONG
1 891 405
BRITISH EAST INDIES
14 876 298
DUTCH EAST INDIES
5 580 267
DUTCH WEST INDIES & DUTCH GUIANA
872303
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ARGENTINE REPUBLIC
3 740 752
AUSTRIA
3 389 816
BELGIUM
39 873 043
BRAZIL

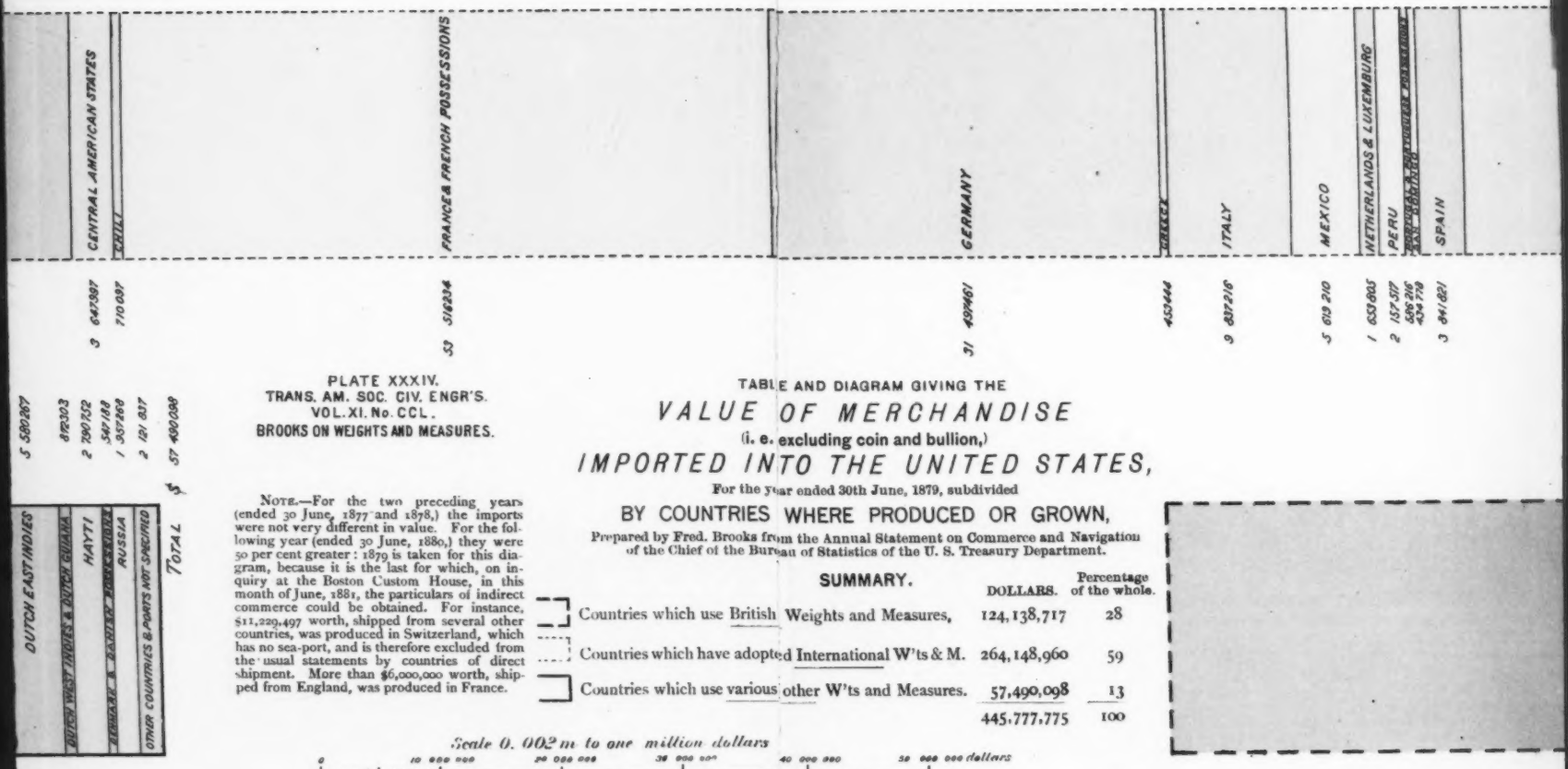

PLATE XXXIV.
TRANS. AM. SOC. CIV. ENGR'S.
VOL. XI. No. CCL.
BROOKS ON WEIGHTS AND MEASURES.

TABLE AND DIAGRAM GIVING THE

VALUE OF MERCHANDISE

(i. e. excluding coin and bullion,)

IMPORTED INTO THE UNITED STATES,

For the year ended 30th June, 1879, subdivided

BY COUNTRIES WHERE PRODUCED OR GROWN,

Prepared by Fred. Brooks from the Annual Statement on Commerce and Navigation of the Chief of the Bureau of Statistics of the U. S. Treasury Department.

NOTE.—For the two preceding years (ended 30 June, 1877 and 1878,) the imports were not very different in value. For the following year (ended 30 June, 1880,) they were 50 per cent greater: 1879 is taken for this diagram, because it is the last for which, on inquiry at the Boston Custom House, in this month of June, 1881, the particulars of indirect commerce could be obtained. For instance, $11,229,497 worth, shipped from several other countries, was produced in Switzerland, which has no sea-port, and is therefore excluded from the usual statements by countries of direct shipment. More than $6,000,000 worth, shipped from England, was produced in France.

SUMMARY.

	DOLLARS.	Percentage of the whole.
Countries which use British Weights and Measures,	124,138,717	28
Countries which have adopted International W'ts & M.	264,148,960	59
Countries which use various other W'ts and Measures.	57,490,098	13
	445,777,775	100

Scale 0. 002 m to one million dollars

LE AND DIAGRAM GIVING THE

OF MERCHANDISE

(excluding coin and bullion,)

TO THE UNITED STATES,

ar ended 30th June, 1879, subdivided

WHERE PRODUCED OR GROWN,

m the Annual Statement on Commerce and Navigation
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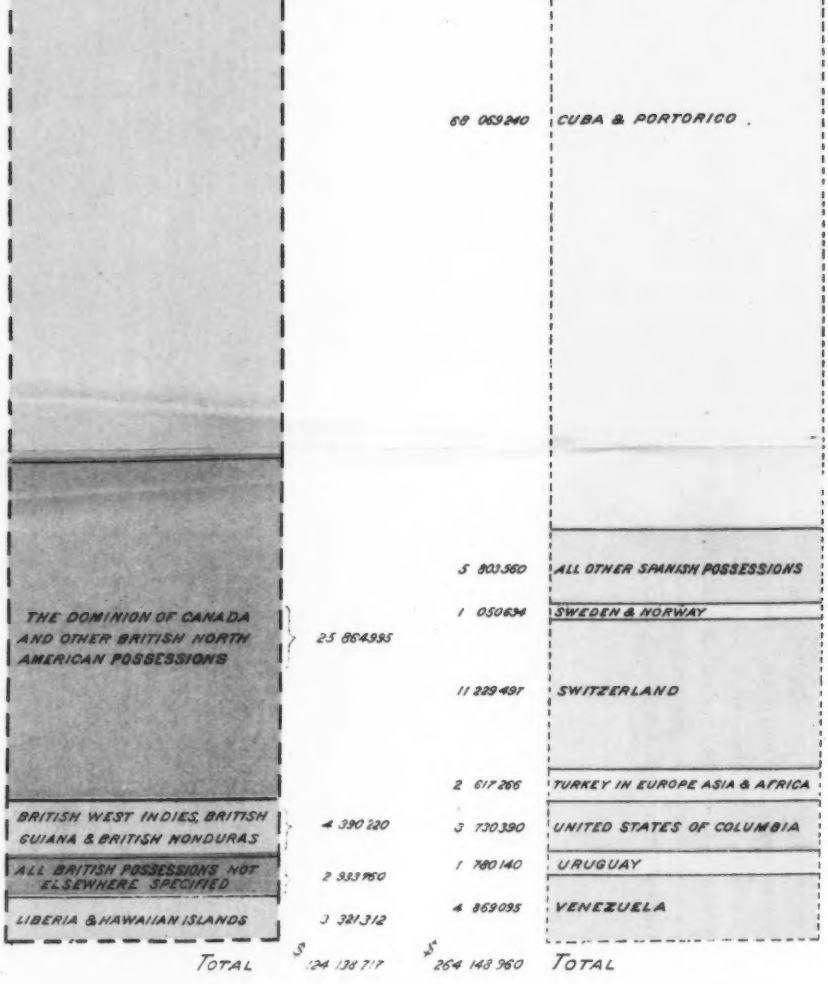
	445,777,775	100

40 000 000 50 000 000 dollars


68 089 240
CUBA & PORTORICO .
$ 803 560
ALL OTHER SPANISH POSSESSIONS
1 050 634
SWEDEN & NORWAY
11 229 497
SWITZERLAND
2 617 266
TURKEY IN EUROPE ASIA & AFRICA
3 730 390
UNITED STATES OF COLUMBIA
1 780 140
URUGUAY
4 869 095
VENEZUELA
$ 264 148 960
TOTAL
THE DOMINION OF CANADA AND OTHER BRITISH NORTH AMERICAN POSSESSIONS
25 864 995
BRITISH WEST INDIES, BRITISH GUIANA & BRITISH HONDURAS
4 390 220
ALL BRITISH POSSESSIONS NOT ELSEWHERE SPECIFIED
2 933 950
LIBERIA & HAWAIIAN ISLANDS
3 321 312
$ 124 138 717
TOTAL

been the 2-feet rule. And it is remarkable that the duodecimal or Joktanic arithmetic, founded on the natural divisions of the circle, fractionally convenient for minor purposes, and of unquestioned antiquity, has never presented a dimension longer than 144 inches, which survives in our standard length of boards, the joktan of Guinea, the tung of Sumatra, and others less exact. The reckoning has always been by thousands and millions of feet. Of its enormous influence in confounding metrics, mention will be made further on.

To understand the points raised, a brief comparison and historical outline is indispensable. Much of the outline has to be filled in by severe induction, keeping within strong probabilities, and in range with visible points.

The means of comparison is the ancient Egyptian and Phenician schœnus or land-chain—a length of $145\frac{92}{100}$ English feet. The cubit was its $\frac{1}{100}$ part, and the fathom (fedan) 3 cubits; the stadium 100 fathoms, and the *great* schœnus 100 stadia, or ten miles. The Persian parasang was 50 stadia, or 5 Egyptian miles. Their cubit agreed with the Egyptian. It is at once apparent that the Egyptian itinerary was a surprisingly exact decimal of the *mean* terrestrial great circle, as we now understand it, divided into 3 parts; and the parasang, into 6. The agrarian schœnus and cubit, consequently, were empirical decimals of the division into 9. Astronomers divided the celestial circle into 12 parts; and there was the obvious division into 4 and 8. The general arithmetic was decimal. For reasons presently apparent, the divisions of the circle by 24, 5, 10 and 15 were probably known. Here was a system which, on the whole, compares favorably at least with the French. But there existed among builders the duodecimal fancy in arithmetic, reckoning from the thumb or inch. Successive bisections of the joktan gave the vulgar fathom, the yard and the 18-inch cubit, now largely represented in the East Indies. This was in direct collision with the ancient cubit of $17\frac{5104}{}$ English inches.

One feature of the experiment on the plain of Shinar, which failed politically, was a consolidation of metrics by merging all the factors into a general system. The circle was divided into 360 degrees, so as to embrace the ungeometric divisor, 9; and to make things strong, both the degree and hour-angle were subdivided sexagesimally. A cubit was invented, subtending one degree on a radius of 100 duodecimal feet, that is, 21 inches, or more strictly, $1\frac{74533}{}$ feet. This metric scheme was

adopted by the first Assyrian monarchy, and divers features of it dispersed among the migrating colonists.

Then came the Hebrew system, a striking mosaic.* The arithmetic was decimal. The cubit was taken at $\frac{1}{8^0}$ of the agrarian schœnus, the fathom, 4 cubits instead of 3, the stadium 100 fathoms, and the mile 10 stadia. So that the great schœnus was 60 stadia, as quoted by lexicographers, and the parasang 30, or 3 miles. The itinerary was an even decimal of the terrestrial division into 18 parts, and the half mile or Sabbath-day's journey matched with the Babylonian degree. A 3-cubit fathom would match an itinerary founded on the hour-angle, such as appears in the Turkish mile, and is traceable in the braza and toesa of Spain and Portugal, the toise of Lorraine and Liége, the tesa of Turin, and any number of cañas, klafters, passos, and the like, in various parts of Europe. The radial cubit, of which all the rest were known functions, was not obtruded, but reserved for purposes of arbitration, under the strongest safeguards against violation, loss or destruction. The inch seems to have settled at a pure decimal of the double diameter or square cross. The unit of capacity was a cubic duodecimal foot, divided decimally, but with fractional divisions for commercial convenience, each of which was even inches. The unit of weight was half a thousandth of the weight of the capacity unit in water (the ratio of the cone to the sphere), and was monumented in silver money. It is traceable in the avoirdupois ounce, originally a double shekel weight. There was a Hebrew foot, so called, not a part of their system, but simply a portable tenth of the joktan, for reference. It has caused much confusion by being divided duodecimally among those who mistook its true import.

A few years after the overthrow of the Jewish kingdom, and the forced expatriation of the people, and pursuant to an understanding between the subjugated leaders and the Medo-Persian alliance, then about at its zenith, Ezekiel drew up a plan of the restoration. He set up the radial cubit as the common measure of temple, glebe, city and inheritance. His arithmetic was decimal. He vindicated geometry, and

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* This system is rather referred to as an existing fact, than ordained in the Institutes. Traces of it, in connection with others assignable to the other systems, in the metrics of China, An-Nam and the Burmese peninsula, before the interference of Europeans, suggest that it may have been a device of thinkers at the time of the dispersion to mitigate the evils likely to grow out of the Babylonian plan. A curious division of the diurnal cycle into 18 parts appears in the "Book of Enoch," translated from the Ethiopic.

proclaimed the divorce of direct measure from circular and itinerary, by suggesting a reed of six radial cubits, which would geometrically span but not measure the circumference. [In the sequel, the kaneh, or builder's reed, seems to have settled at 4 radial cubits, or the double diameter.] Itinerary was not interfered with. The old system of weights, capacity and money was allowed to stand, with marked emphasis upon decimal relations.

After the Macedonian conquest, various foreign measures were introduced into Egypt, and metrics became much confused.* Matters were made worse by the Greeks and Romans, whose itineraries were founded on the military pace. As a climax, the Roman Government, having finally denationalized the Jews, sunk the sacred cubit in the Tiber.

This rather meagre outline explains many things which have been obscure. Among other things, it reconciles in an unexpected way the apparent conflict of mathematicians during the old revival of letters as to the size of the earth. Before the Macedonian conquest, Aristotle had announced it as the opinion of geometers that the circumference was 300 000 stadia. Archimedes made the same statement 200 years later. Twenty years further on, Eratosthenes, by altitudes of the sun at Syne (Assouan) and Alexandria, computed it at 250 000. Posidonias, 140 years later, using a star at Alexandria and Rhodes, deduced 240 000; 260 years more, and Ptolemy, from careful measurements in Egypt, brought it out at 180 000. It is too much for belief that these eminent men, all educated in Egypt, or any one of them, blundered seriously, or used less ingenious contrivances than the odometer wheel and big wooden triangles of Fernel, in France, in 1525. But if we assume that Aristotle and Archimedes reckoned by the Egyptian itinerary; Eratosthenes by a 3-cubit fathom upon the Babylonian or royal cubit; Posidonias in like manner upon the Mosaic cubit, as the Saracens did; and Ptolemy by the Jewish itinerary,—the results agree.

Metrics are now so confused that a compromise, in the nature of the older Hebrew system, is impossible. The downfall of ancient systems, founded on the circumference of the earth, has been accelerated partly by defective divisions of the circle, and still more by the radical fault of using part of the arc—a function—instead of radius, as a metric base. And the French is no better; in fact, worse. And all attempts of gov-

* A schoina, quoted by Mr. Alexander, is simply an imported parasang.

ernments to mend matters by artificial adjustments have but increased the trouble.

One of the most instructive instances of this bungling—because so pretentious—was the English attempt to fit duodecimal arithmetic into itinerary and the English land measure. The latter is of Oriental origin. Acre is a Persian word, and perch a modified Roman name for a Persian thing. To understand the movement, it should be noticed that the radial cubit was always in a somewhat perplexing relation to the 2-feet rule of the builders. To enlarge the latter would destroy the decimal correlation of the inch; and to reduce the former would mar the measure of inheritance. To prevent confusion, the radial cubit was disused among builders, without any assertion on their part that the 2-feet rule was or ought to be a veritable unit. In their symbolic system, its division is explained to refer to *time*. It is not a measure, but a witness, an index to the circle, whose properties are to be learned by geometry; and it suggests division by three and the parallels. In the face of this broad hint, the philosophers lugged in the yard, a quarter as long as a standard board. The rod was clipped to 198 inches, $5\frac{1}{2}$ yards; the perch of England and Ireland stretched to 252 inches, 7 yards. Taken as a diameter, 7 yards, by Archimedes' rule, demands a circumference of 22, a perfect decimal chain of 100 new-born links; the broad acre was made 10 square chains, 10 times as long as broad; but reduced to a square, its side is neither perches, yards, chains, links, feet or inches. But the circle was squared "according to Gunter," by board measure. The mile was made 80 chains, and fits nowhere. It is doubtful if the inch escaped degradation. The Pyramid, with the height of its remaining frustum to the theoretical height as 24 to 25, can scarcely be called a "witness" to existing measures, unless on the score of martyrdom. It is beheaded, skinned and well-nigh disemboweled.

I have elsewhere (correspondence on Standard Time) suggested an arrangement on the radial cubit with a correlated inch, without the duodecimal tangle, and with itinerary founded on the hour-angle.

From a cursory examination of Alexander's "Weights and Measures," published 32 years ago, it is apparent that when the present French system was instituted, the number of available analogues in Europe and the East, susceptible of adjustment into a more perfect system, stood about as follows:

Radial cubit,	175,	of which were in	France	and	dependencies	12.
Metric perch,	12,	"	"	"	"	6.
" rod,	30,	"	"	"	"	6.
" reed,	40,	"	"	"	"	12.
" acre,	35,	"	"	"	"	15.
" fathom,	28,	"	"	"	"	6.

The inch being subordinate, it seems a fair question whether, for a general system, weights and capacity should not be founded on the radial cubit. Engineers, from their training, are as able to endure the present evils as are other men. But this very fact makes them keenly alive to existing defects; and at the same time, as a matter of foresight, inclined to deprecate changes hastily made; and particularly, in the light of past human experience, to avoid invoking governmental interference, until it shall clearly appear to the public, as well as to themselves, that such changes are in the direction of ultimate maximum propriety and utility.

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CCLI.

(Vol. XI.—December, 1882.)

ON THE CARE AND MAINTENANCE OF IRON BRIDGES.

By HENRY D. BLUNDEN, M. Am. Soc. C. E.

READ OCTOBER 18TH, 1882.

WITH DISCUSSION

By THEODORE COOPER, M. Am. Soc. C. E.

Many valuable papers have been both read and discussed before this Society on the design and construction of iron bridges, but of their care and maintenance after erection we have heard very little. Indeed, it seems to be the prevailing opinion among almost all classes, that when an iron bridge is once erected, painted and the floor down, it is to last forever, requiring no care except an occasional coat of paint, and as an omission of this latter does not immediately affect the strength of the structure, it is frequently neglected.

After a close examination of a large number of bridges in different parts of the State during a period of nine years, I am satisfied that they are invariably shamefully neglected.

As a general rule, the immediate care of iron bridges is left to men who know nothing either theoretically or practically of the design or manufacture of the structures they look after. To screw everything up tight seems to be the order of the day, regardless of consequences. If a rivet becomes loose they replace it—perhaps the same rivet two or three times in as many months—seldom asking why such rivet becomes repeatedly loose.

Some of the causes of undue wear and tear to bridges are as follows:

The ties not having an even bearing on the stringers, with rails not properly spiked to the ties. The result of a passing load, with this condition of affairs, is a constant pounding, first from the rail to the tie, and then from the tie to the structure. Imperfect track at the bridge approaches, and too large openings at rail joints immediately on the bridge, are often the causes of very severe shocks.

The expansion gear (rollers, &c.) is generally out of sight and hardly ever kept clean. Insufficient freedom is often the cause of serious trouble. The writer, in 1875, saw the fixed end of a 180-feet span, double track railroad bridge push the granite pedestal to which it was bolted into the back wall, on account of the free end being blocked by the fixed end of the following span.

Improper anchoring down of the fixed end is another source of trouble, especially if the bridge be on a grade. For instance, in a double track, two truss, through bridge, the tendency is for one of the trusses to move in the direction of the traffic, the other remaining nearly stationary; in such a case the lateral system has a good deal more to do than it was designed for.

Poor masonry is also the cause of much mischief. No amount of anchoring or care with the rollers is of any use, unless the masonry be in a condition to resist the thrust of expansion and contraction of the structure.

The free action of friction rollers is often blocked by the accumulation of dirt in front of and around them; cinders ground to powder by the action of the rollers will, after being moistened by rain, form a concrete so hard that a hammer and chisel are required to remove it. If this is not frequently done the movement of the rollers will eventually

be prevented, and the truss must then buckle, slide on top of the rollers, or move the bed plates.

Cast-iron pedestals are often so constructed that drain-holes are necessary. When these holes are over the rollers they invariably become channels for all kinds of dirt as well as water.

Imperfect, or rather uneven, adjustment of the laterals will give a wavy motion to the trusses under passing loads, causing a working at the joints. This is especially dangerous with cast-iron chords or wrought-iron chords with cast joint boxes.

In bridges with floors suspended from U bolts, severe shocks are often given to the structure by the uneven bearing of the cross-beam on its seat. If the hangers be in pairs, unless most carefully tightened up and the seat given a uniform bearing, one pair will carry by far the largest part of the load. The same trouble occurs with the stringer seats on the cross-beam.

The over tightening up of the counters will relieve the main rods and chords of a part of their dead load. Under this condition of things, on a load being applied, the counters are improperly strained, and the main rods and chords receive more or less shock, ending in the final breaking of the counter. If the chords be not properly packed, a chance is given for the eye-bars to move; the result of this is either the cutting of the pin or the distortion of the pin-hole.

The writer tested a sample cut from a counter broken under the above-mentioned conditions, with the following results:

Ultimate, 44 000 pounds per square inch.

Fracture, large crystals.

Elastic limit, 36 000 pounds per square inch.

No elongation.

No reduction.

Although corrosion may not materially affect the strength of a bridge for many years, it most assuredly will in the long run. The writer, in the case of one railroad crossing over another, removed from a three by ($3'' \times 1''$) one inch flat bar of iron, in the bridge, scales almost one ($\frac{1}{16}''$) sixteenth of an inch thick; this bridge had only been erected (10) ten years, and had been painted twice.

Without going into the question of design, there is one point that appears to the writer as faulty. For instance, in a double track, two truss, through bridge with four parallel stringers, it is customary for

the truss pedestals to rest on friction rollers at one end, and to be bolted to the masonry at the other, while the ends of the stringers rest upon sliding plates or a timber wall plate bedded on masonry.

To obtain uniform results, should not the ends of the stringers rest upon a beam connected to the end pedestal, thereby throwing the entire weight of the structure on the two fixed and two movable points?

False economy is often the cause of a very poor floor. For the sake of saving a few pounds of iron, the flange section of a stringer is made of two angles and a short cover plate, thereby necessitating a variety of notching down to give the ties an even surface. A section of two larger angles would obviate any notching except the ordinary sizing of the tie.

Corporations very seldom take into consideration the cost of a floor and its future maintenance in canvassing proposals for bridges. Many of those now built have floors which it is almost impossible to renew, either in whole or in part, without disturbing the entire structure.

Suggestions for the Care and Maintenance of Iron Railroad Bridges.

Track.—The track for a distance of 500 feet on each side of the bridge must be kept in perfect line and surface. If on a curve, the proper super-elevation should be maintained and the rails carefully bent, not sprung, to the required radius.

When a bridge is at the foot of a grade, an elastic timber floor, upon which the rails are to be placed, must be carried back from the abutments at least 50 feet. This is especially necessary when the filling behind the abutments is of material easily affected by the frost.

Ties.—Ties must be of sawed timber, evenly spaced and carefully sized to a uniform depth at the stringers, upon which they should have a full and even bearing. Whenever a tie becomes soft and is cut into by the stringer, or by the rail, a hard wood shim must be used until the tie can be replaced. The rails must be well spiked and drawn down to every tie; and at the lowest temperature the opening at the rail joints must not exceed $\frac{1}{8}$ of an inch.

Guard Timbers.—Guard timbers, notched and screw-bolted to the ties, must be placed upon every bridge; they must be drawn down tight to the ties and kept so. Whenever the guard timbers extend be-

yond the bridge, they must not be rigidly connected with the guard timbers upon the bridge. All old spike and bolt holes in ties or guard timbers must be plugged.

Wall Plates.—Where timber wall plates are used, care must be taken to give them a full bearing upon the masonry.

Masonry.—The piers and abutments must be kept clean and free from cinders and refuse material. All joints should be well pointed up, and frequent examinations made to detect fractures, or any signs of unequal settlement or movement of any kind. Whenever the masonry appears in the least degree insecure, a detailed statement of the facts should be sent at once to the Chief Engineer.

Iron Work or Bridge proper.—Frequent and careful inspection must be made of all the iron work of the bridge, and especial care given to the friction rollers, pedestals and cast-iron work as being the parts most liable to give trouble. The rollers must be kept clean, so that they can move readily, and also be placed and kept at right angles to the line of bridge. If they cannot be cleaned from the outside, the trusses must be raised, the roller frames taken out, cleaned and replaced. Pedestals must be examined frequently to see if they are cracked or otherwise insecure. The nuts on the anchor bolts must be set up tight, and the drain-holes, if any, kept free and clear.

Cast-iron in any form is objectionable in a bridge, and particularly so when in the shape of chord joint boxes. These require constant watching, particularly in cold weather; and should any cracks or imperfections be discovered, a report of the defect, as much in detail as possible, should be at once submitted to the Chief Engineer.

The rivets in the bridges should be examined from time to time, and loose ones cut out and replaced as soon as possible. If the web sheet be torn and the hole becomes elliptical, it should be reamed out and a larger rivet inserted, that is, provided the elongation be not more than $\frac{1}{8}$ of an inch greater than the diameter of the old rivet. Should the plate be torn to a greater extent, or the rivets after replacing become repeatedly loose, a full and accurate description of the defective parts should be submitted promptly to the Chief Engineer.

When a bridge has been put in proper adjustment, the nuts and turn-buckles on the hangers, counters, lateral and sway-rods must be clamped in place and not altered. In bridges of ordinary span all of the parts will expand and contract so nearly alike, that loosening or tighten-

ing the rods is unnecessary, and only productive of excessive strains in some of the members of the truss.

Examinations.—Thorough examinations of every bridge should be made as often as possible, certainly not less than once in every thirty days, and more frequently upon those bridges which have some special weak points. Everything pertaining to the bridge and its surroundings should be carefully inspected, and a report, giving the condition of the masonry, superstructure and track, with any recommendations thought necessary, should be forwarded to the Chief Engineer, and in no case must extensive repairs or any alterations be made in a bridge until the same shall have been approved by him.

Painting.—All of the iron work should be painted at least once in every three years, but should rust spots appear between the periods of painting, they must be scraped and re-painted as soon as detected.

Whenever the entire structure is to be painted, all rust must be thoroughly scraped off or otherwise removed, and the new paint applied evenly and not daubed on.

The above suggestions are presented by the writer as the result of an extended experience on a long line of road (the New York, Lake Erie and Western), with the hope that engineers of other railroads will also submit their ideas, and that out of the resulting discussion a greater knowledge of this important subject may be generally disseminated among those having the care of such structures. Greater safety to the public will certainly be the result.

DISCUSSION

ON THE CARE AND MAINTENANCE OF BRIDGES.

By THEODORE COOPER, M. Am. Soc. C. E.

The rusting or corrosion of wrought-iron at ordinary temperatures is a very important matter of consideration.

The example given by Mr. Macdonald* of the corrosion of an iron rod set in sulphur is not an uncommon one; numerous instances, however, can be given where iron set in sulphur has not corroded. The explanation, to the writer's mind, is a simple one. There is no chemical action between pure sulphur and iron at ordinary temperatures; these two elements only uniting at high temperatures—above red heat. But ordinary commercial sulphur generally contains sulphuric and sulphurous acids, produced by the oxidation of the sulphur during its process of sublimation. These acids are the immediate corroding agents when the impure sulphur and iron are in contact.

Such sulphur should be thoroughly washed before being used.

In general, the rusting or corrosion of iron only takes place in the presence of an acid and moisture.

In dry air at common temperatures, or under pure water free from air and carbonic acid, iron does not oxidize. Neither does it oxidize in dry carbonic acid gas; nor to any great extent, if at all, in damp oxygen. But in the presence of moisture and many acids the corrosion takes place readily and continuously.

The most common agent towards corrosion is carbonic acid gas.

Prof. Calvert found that damp air with a slight addition of carbonic acid produced a rapid oxidation; the process being, first a production of protoxide of iron, changing to the carbonate and then passing to the hydrated oxide or ordinary rust. Though the carbonic acid was the active agent in bringing about the combination, the carbonate of iron remained in small quantity—an apparent process of transfer or disposing influence.

As our atmosphere contains carbonic acid gas and aqueous vapor, and as all natural waters contain air and generally carbonic acid in solution, the rusting of iron is universal. It varies, however, in the degree of rapidity according to the conditions of the special location; the

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* In a verbal discussion of the paper on the care and maintenance of bridges.

dryness of the air in certain regions making the action an exceedingly slow one, while in others the excess of moisture and gaseous acids produce an exceedingly rapid corroding action. In tubular bridges, tunnels covered with iron girders, and the overhead parts of bridges, the iron work is especially subject to corrosion, due to the excessive amount of moisture (condensed steam), carbonic acid and frequently sulphurous acid discharged upon the exposed surfaces from the locomotives.

While the sulphurous acid, if present, is a very active agent in promoting corrosion, the greatest factor is undoubtedly the carbonic acid gas. An analysis of a sample of rust taken from the Conway Bridge gave—

Sesquioxide of iron	93.094	per cent.
Protoxide "	5.810	"
Carbonate "	0.900	"
Silica	0.196	"

Mr. Wm. Kent found in rust taken from a Pennsylvania Railroad bridge, where it was exposed to the action of the escaping gases, carbonic acid in considerable quantities, but only traces of sulphuric and sulphurous acids.

Under fresh or under salt water the corrosion of iron is largely influenced by the presence and amount of air and carbonic acid gas.

The action generally appears to be greater where the iron is alternately wet and dry.

The caustic alkalies and alkaline earths prevent the oxidation of iron by neutralizing the acids. Iron, therefore, does not corrode in alkaline solutions or when imbedded in lime.

The testimony in regard to the action of a thin coating of lime whitewash upon iron is contradictory. The writer has seen many cases where whitewash has corroded iron rapidly; others testify to its thorough preservative qualities. The difference may consist in the addition of other ingredients to the solution; for example, it is often customary for whitewashers to add common salt to the lime solution to increase the hardness of the coating; again, others add glue or similar material to the lime to increase its adhesive qualities. The one containing the salt would undoubtedly corrode the iron, and the other with the glue would not do so. Whether a thin layer of lime only, after the lime had taken up its full equivalent of carbonic acid, would continue to act as a preservative, is doubtful; for from its hydroscopic character it would readily convey moisture charged with the destructive acid in to the surfaces of the metal.

As to hydraulic cement, the evidence is not so positive. Mr. Thos. C. Clarke, M. Am. Soc. C. E., says, in his report upon the Niagara Bridge, that on uncovering the anchorage links he found the iron as perfect as when put there, without the slightest sign of rust, though the mortar was saturated with moisture and the whole foundation evidently surrounded by water-bearing strata of rock. Genl. M. C. Meigs says he found a wrought-iron pipe laid in cement concrete, honeycombed and leaky after twelve years' time, and he learns from plumbers that in their experience American cements corrode iron.

This different testimony in regard to the action of cements may possibly be explained by the different circumstances of each case—such as the relative compactness and depth of the cement in which the iron is imbedded.

There is a possibility, however, that in certain cements the silicates may be soluble in water, and thus furnish the acid agent toward corrosion. Mineral wool made from furnace slag very closely approximating the composition of hydraulic cements has been found in certain cases to corrode iron very rapidly. It was claimed that this was entirely due to the hygroscopic character of this material, but recent instances reported to me would appear to lead to the belief that the wool in the presence of water not only corrodes the iron, but also disintegrates and hardens into a solid mass.

Wet coal ashes corrode iron very rapidly.

Mr. Wm. Metcalfe, M. Am. Soc. C. E., states that a wrought-iron pipe buried in coal ashes was completely eaten away in one year's time.

As a curious instance of the slight causes which promote oxidation, the experience of a manufacturer of fine cutlery was related to me. He found at one time a large portion of his goods being returned to him as in damaged condition ; instead of the bright clean surfaces for which such articles are noted, he found rusty, deeply oxidized blades. After much anxiety and watching to determine the cause, whether it was damp paper, the ill-will of some of his agents, or other cause, it was located upon the man who sorted and wrapped the knives into packages. Everything he touched was found to rust, from the peculiar acid character of his skin exhalations.

Similarly, it is well known that some persons cannot carry pocket-knives or bright iron articles, as keys, etc., about their person without their becoming very rusty.

The rusting of iron proceeds with great rapidity after it has once commenced, because the rust of iron is a ready absorber of moisture and gases, and it thus constantly conveys new elements of destruction in to the yet unchanged metal.

It is to this fact that the great difference in the rusting of used and unused rails, machinery and tools, is due. The jars and vibrations to which the one is subjected keep the surfaces clear of accumulated rust, that would act as storage reservoirs for the corroding elements.

There is often much misconception in regard to the amount of iron contained in a certain thickness of rust. Dense compact rust may contain enough iron to equal $\frac{1}{4}$ or $\frac{1}{5}$ of its thickness, but the looser and more common kind of rust will not contain over $\frac{1}{8}$ of its thickness in pure iron. In other words, rust $\frac{1}{4}$ inch in thickness will contain from $\frac{1}{16}$ to $\frac{1}{32}$ inch of iron, according to the density of the rust.

The preservation of iron from corrosion is a subject of vast importance, and has given rise to many expedients more or less effective, such as alloying iron with other metals, as chromium, tin, copper, arsenic, &c., to obtain a less corrodible metal; plating the surfaces with other less oxidizable metals, as nickel, tin, copper, silver or gold; coating with zinc, a metal that is readily oxidized upon the surface, but whose oxide, when formed, becomes a protection to any further oxidation (when not subject to other acids than carbonic acid gas); coating with fused mineral enamels; covering with laquers; coating with magnetic oxide of iron by the processes of Barff or Bower, by subjecting to high temperatures and the presence of moisture; and lastly, the use of paints of innumerable characters.

For general engineering structures, the coating given to iron surfaces for their protection against corrosion must be not only moderate in cost, but of such a character as to be readily renewed when removed by accident or design. It must also differ from zinc in being able to resist the corroding action of sulphurous acid gas and the chlorides, in locations where these may occur.

This practically reduces us to the use of paints (using this term to include not only the paints proper, but varnishes, oils and other materials applied in a liquid form). The relative merits of the paints depend upon their durability, adhesiveness and imperviousness. The cracking of the paint and want of adhesion produced by too rapid drying of the paint, and the want of adhesion due to the presence of rust upon the surfaces

of the iron, are the most frequent causes of failure in the better classes of paints. All rust should be carefully removed from the surfaces of the iron before painting; a coat of raw linseed oil then makes an excellent covering for the surface, elastic, perfectly adherent, and a good durable substratum for future coverings. In order to get our iron work out of the shops quickly and in a condition to be handled, we resort too often to quick-drying paints, to the future injury of the work.

As to the pigment to be used for the covering of this substratum, red lead, oxide of iron, &c., each have their own advocates.

The maintenance of iron bridges is so dependent upon the detail of their design, and the method and character of the inspection, that it is very important, both from points of economy and of safety, that the supervision of these points should be given to competent men.

The original design affects the maintenance and care of our bridges, not only by the form and proportions of the structure and its details as to strength, but also as it affects the accessibility for cleaning and painting, the freedom from lodgment of water and dirt, the amount of surface exposed to corrosion, the number of parts subject to adjustment, and the facility of repair and renewal of the ties or wooden floor.

The writer has seen bridges recently constructed, and which have been accepted by engineers of an important railroad, that have their wooden floors built into the iron work in such a manner that a broken or decayed tie cannot be replaced except by removing the whole bridge floor.

The inspection of bridges should be something more than the superficial examination of the track-walker. To know that every member is doing its duty properly, and to discover the reason when such is not the case and the remedy to be applied, requires the supervision of a more intelligent class of men than usually are delegated to this work.

Of hundreds of bridges examined during past years by the writer, it would be safe to say that not more than ten per cent. of them were found in a condition to do their best duty; many were badly neglected, and some positively dangerous; all showing a positive want of intelligent inspection and supervision. It would undoubtedly be true economy, and certainly a just duty to the public, for every railroad to have its bridges carefully and intelligently examined at least once a year by a special expert. If it accomplished no other end than to check and educate the ordinary local inspectors in a proper execution of their duties, it would pay for the expense.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCLII.
(Vol. XI.—December, 1882.)

A PECULIAR PHASE OF METALLIC BEHAVIOR.

By O. E. MICHAELIS, Captain of Ordnance, U. S. Army, M. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, MAY 17TH, 1882.

WITH DISCUSSION

By T. EGLESTON, M. Am. Soc. C. E.

Last September, in the ordinary course of business, an invoice of so-called gilding metal, presumably an alloy of copper and zinc, was received at the Frankford Arsenal, the Government cartridge manufactory. I am somewhat cautious in the use of descriptive terms; for up to the present, for various reasons, I have not succeeded in witnessing the mixing, melting, casting and rolling of the metal.

The contractor, owing to the uniform success of his output, has been deservedly considered the maker of our standard sheet cartridge copper.

This particular delivery was subjected to the usual treatment, met every demand, underwent every proof, in the customary satisfactory manner, but failed in the firing test. The contractor was notified, at once appeared, and saw convincing evidence of the failure. He stated positively that this especial lot of metal had been treated in precisely the same manner as the accepted invoice immediately preceding it, and that he was unable to account for its shortcoming. After a moment's reflection, with a smile of apparent satisfaction, he turned to me, saying: "By George, it must be something in the air here."

Tests.

The tests to which cartridge metal is subjected may be divided into—

1st. The shop, or working test.

2d. The laboratory test.

3d. The powder-proof.

The shop test includes a careful inspection, by trained men, for discoverable defects, the fabrication of, say a thousand, shells in the ordinary way, under the immediate observation of expert attendants, and the running through of a limited number without annealing. This last may be called the crucial working test. Card No. 1 (Plate XXXV.) shows its progressive stages. The severest trial to the metal is, probably, the reduction in the tapering machine; if it be an inferior or unsuitable material, the case will buckle or split.

Only thorough honesty and consequent adaptability will enable the metal to sustain the searching practical strain upon its integrity, due to the "cold shut" drawing, heading and tapering incident to this proof.

The laboratory test includes the determination of the mechanical qualities of the metal, principally by means of a "Thurston Autographic Recording Testing Machine," specially built for the purpose at the Stevens Institute.

The usual autographic strain-diagrams, exemplified in the accompanying plates XXXVI., XXXVII., XXXVIII., are obtained, calculated, and the results compared with standards established by experience.

In addition, the metal is subjected to a "bending" proof, intended to serve as a specific test of its ability to stand "folding." Strips, ¼ inch wide, are doubled (see Card V., Plate XLI.) under a pressure of 1 200 pounds, and the angle of opening until the metal "gives" is measured, and recorded as the bending angle.

Comparisons of specific gravity are also made in the laboratory, and finished cases are tried in the eprouvette, the final stage of what may be called, for want of a more expressive name, the static inspection of the metal. In the eprouvette, a full description of which may be found in the report of the Chief of Ordnance for 1878, the case is held in a chamber, the counterpart of that of the service arm; a constant weight

PLATE XXXV
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BY O. E. MICHAELIS

I. PROGRESSIVE STAGES IN
THE MANUFACTURE OF
U. S. RIFLE CARTRIDGE SHELLS

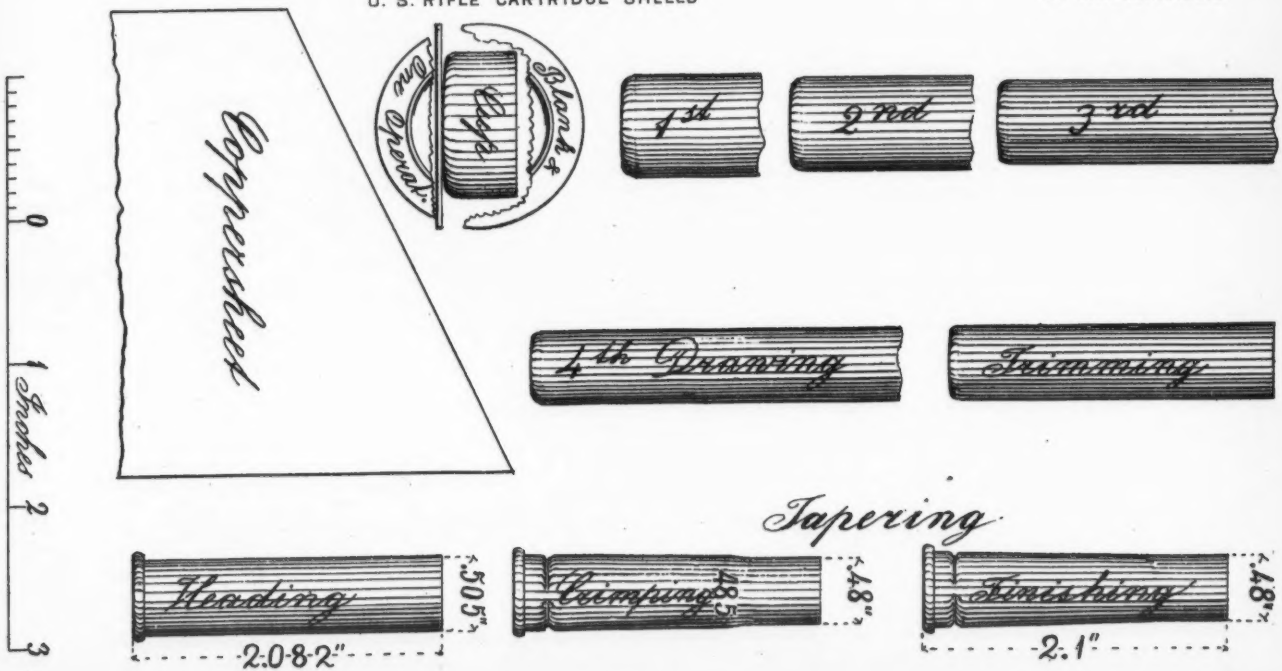

PLATE XXXVI
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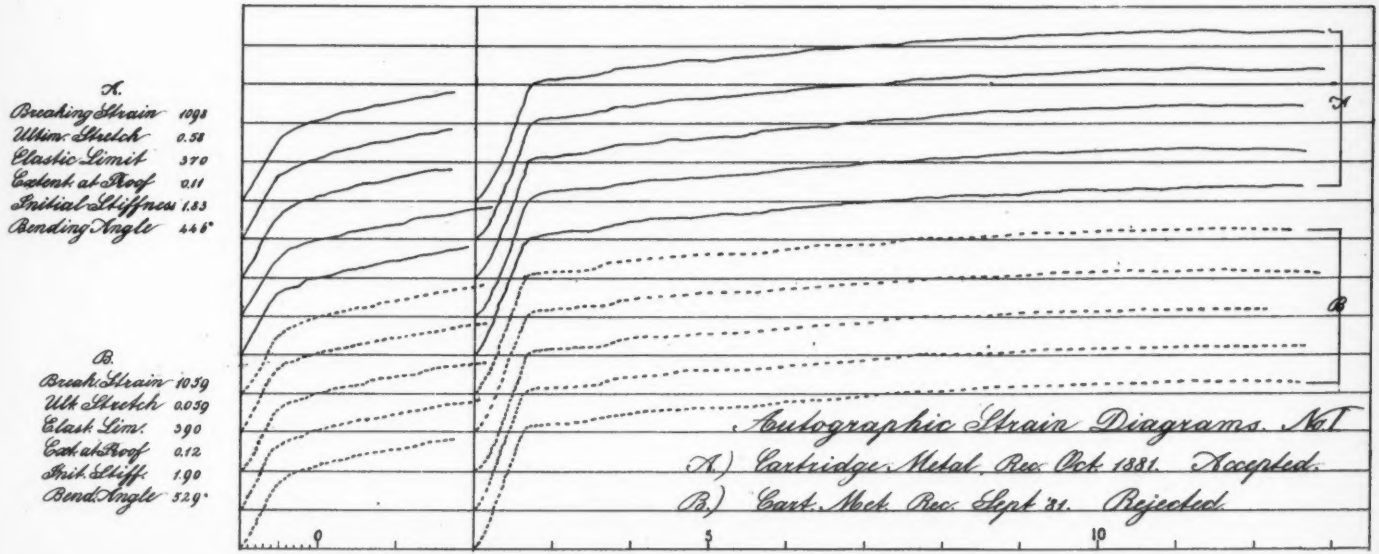

PLATE XXXVII
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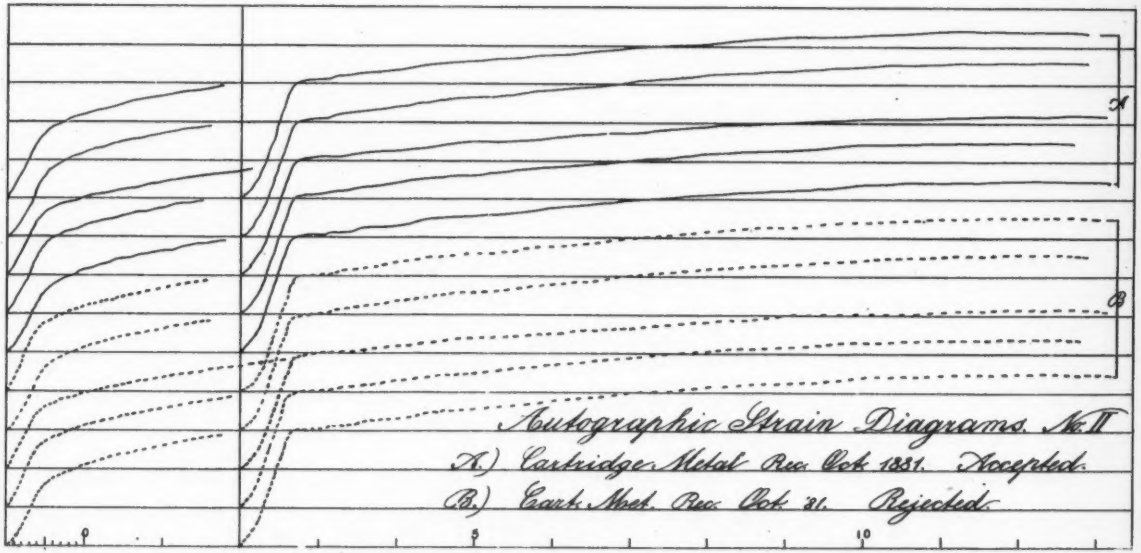

A.

Breaking Strain	1116
Ultim. Stretch	0.57
Elastic Limit	4.17
Extent at Proof	209
Initial Stiffness	1.86
Bending Angle	536°

B.

Breah. Strain	1116
Ult. Stretch	0.57
Elast. Lim.	4.03
Ext. at Proof	0.1
Init. Stiff.	1.93
Bend. Angle	490°

Autographic Strain Diagrams. No. II

A.) Cartridge Metal Rec. Oct 1881. Accepted.

B.) Cart. Met. Rec. Oct '81. Rejected.

PLATE XXXVIII
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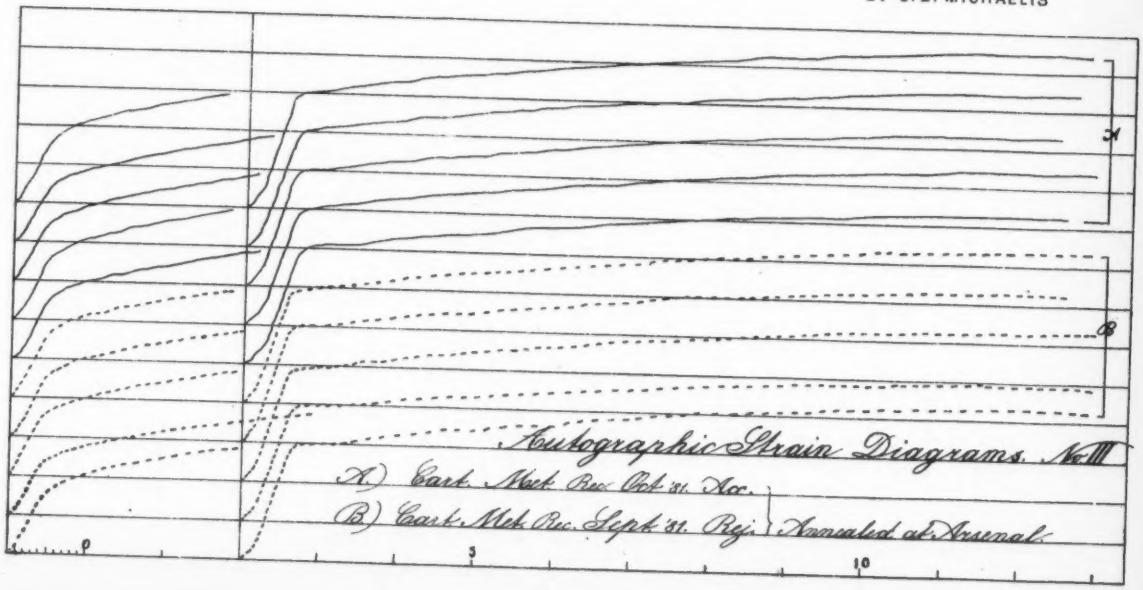
A.

Breaking Strain	109.3
Ultim. Stretch	0.58
Elastic Limit	39.2
Extent at Proof	0.11
Initial Stiffness	1.78
Bending Angle	52.2°

B.

Break. Strain	107.9
Ult. Stretch	0.39
Elast. Lim.	39.7
Ext. at Proof	0.11
Init. Stiff.	1.83
Bend. Angle	48.4°



Autographic Strain Diagrams. No. III

A) Cart. Mat. Rec. Oct. 31. Acc.

B) Cart. Mat. Rec. Sept. 31. Rej. } Annealed at Arsenal.

rests upon its charge by means of an appropriate stem. The smallest weight of rifle powder required to produce the desired effect is taken as an index of the practical value of the worked metal. Cards II. and III. (Plates XXXIX. and XL.) illustrate the results of this procedure.

Card III. (Plate XL.) shows the usual shearing of the head.

A ring is simply pressed out beyond the rigid edge of the chamber—a characteristic of all suitable metal.

Card II. (Plate XXXIX.) shows the rather unusual *phenomenon* of "bursting," a separation between the "fatigued" central portion of the head, under the immediate influence of the punch, and the less tried, because less supported, annular fold.

The occurrence of this phenomenon, under normal conditions (the meaning of this limitation will be explained hereafter), shows that the metal is not suitable for this especial purpose.

We now come to what, in contradistinction, and for a reason already assigned, I will call the dynamic inspection—the powder proof.

The cases fabricated during the shop test are loaded with service charges and bullets, a certain percentage with an established increased charge, and are fired from the service arms; the pressure required to extract the fired cases, a function of the elasticity of the material, being measured, recorded and compared with the standard limits.

This completes the inspection of the metal; the satisfactory accordance of all the tests determines its acceptance.

I have now briefly sketched the severe ordeal through which our cartridge metal must pass before reception, and the behavior of the lot—the occasion of this paper—differed in no respect from its predecessors or successors under these trials, the extraction even being usual; and yet the cases burst in the gun—of course, a fatal defect.

Card I.,* Plate XXXV., shows the working test of this metal—a case drawn, headed and tapered without annealing.

Plates XXXVI., XXXVII. and XXXVIII. are autographic strain-diagrams of this especial metal and the accepted lot which replaced it.

No. 1, Plate XXXVI., was taken at the time of its delivery, and Nos. 2 and 3, Plates XXXVII. and XXXVIII., recently, from reserved sheets. The strips are delivered annealed, but, to make sure of its uniformity, I had some re-annealed, and Plate XXXVIII. shows the result.

*When this paper was read the actual specimens referred to were exhibited on cards. From these specimens the plates have been prepared.

It is unnecessary here to give the data of the diagrams—all were within limits, as may be seen.

Card III., Plate XL., shows the eprouvette proof of both the rejected and accepted metal; no difference of behavior is perceptible.

Card IV., Plate XLI., shows the failure in the gun. During the proof of this metal last September portions of the head were actually burst off, but, unfortunately, I did not preserve these specimens, and in my late experiments I succeeded in obtaining only the class of casualties illustrated on the card. My theory as to the cause of this I will mention later.

Card II., Plate XXXIX., if its results had been obtained in the eprouvette under normal conditions, would show a metal of which bursts in the gun might be predicated almost with certainty, yet the rejected metal gave no indication of this kind.

The cases on Card II., Plate XXXIX., are made from accepted metal, but under abnormal conditions. A die without a counterbore was used in their fabrication, thus enabling me to have the heads "set up" about $\frac{5}{1000}$ of an inch beyond our limit; the consequent increased fatigue demoralized the metal, and it gave way as shown.

From my recent experience with this rejected metal, I may, in passing, say that I believe it in a measure confirms the theory of refreshment first expounded by a member of the Society; it appears to be in better condition now than at the time of its rejection seven months ago.

No adequate reason can be assigned for the final failure of this metal, that so successfully passed through all the exhaustive tests established by extended experience and profound theory. It simply "broke down" in an inexplicable, unexpected manner.

Though but a straw, this failure leads my mind to harbor the heretical misgiving that preliminary static tests of materials furnish data useful only in the solution of questions in the calculus of probabilities. Nothing positive can be drawn from their consideration.

DISCUSSION.

T. Egleston, M. Am. Soc. C. E.—Mr. President: The question of the manufacture of cartridge metal and its uses is one which has interested me greatly for several years past, and on which I have made a large number of investigations. This cartridge metal is not a material of con-

PLATE XXXIX
TRANS. AM. SOC. CIV. ENGR'S.
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BY O. E. MICHAELIS

11. EPROUVETTE TEST
ILLUSTRATING
SHEARING AND BURSTING.

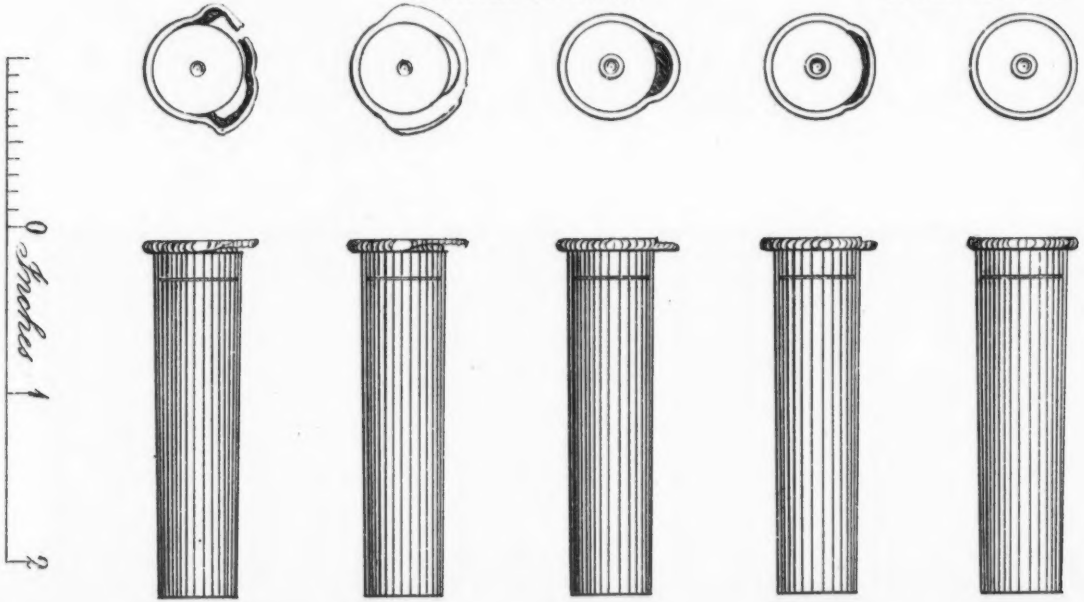

PLATE XL
TRANS. AM. SOC. CIV. ENGR'S.
VOL. XI. No. CCLII
BY O. E. MICHAELIS

III. EPROUVETTE TEST

a, ACCEPTED METAL
b, REJECTED METAL

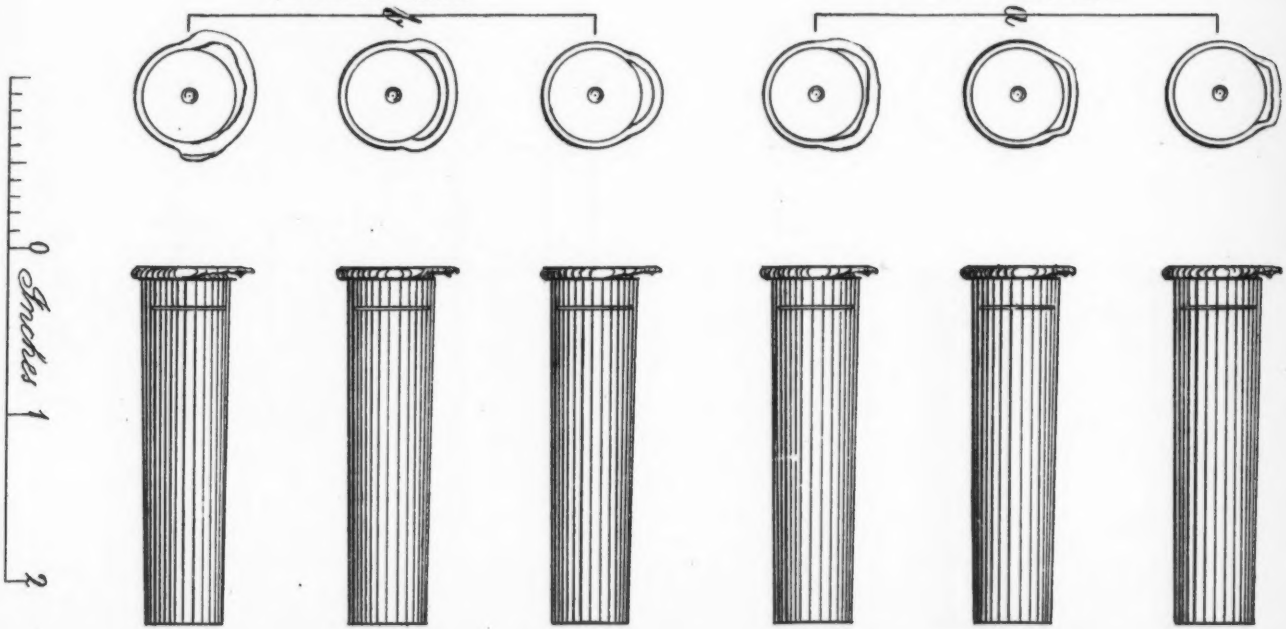

PLATE XLI
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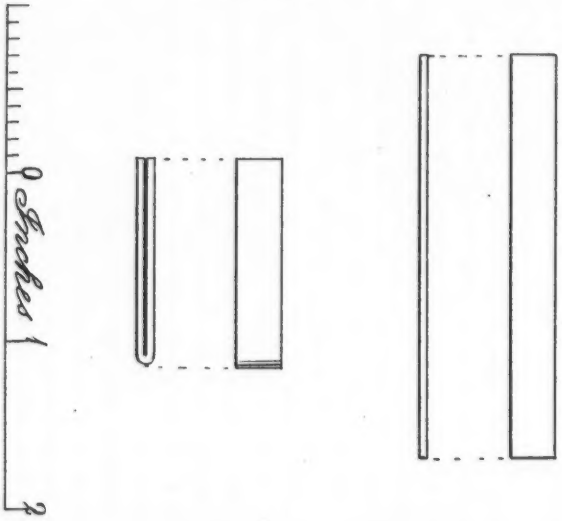
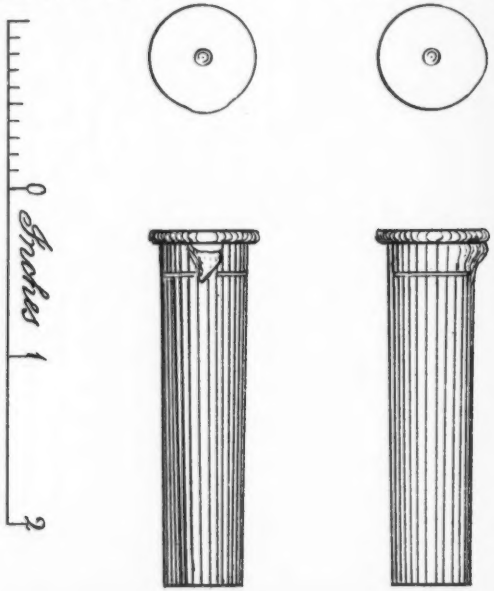
V. BENDING TEST



IV. FIRING TEST
REJECTED METAL
BURSTING IN THE GUN



stant composition. It is sometimes made of brass, containing a very large quantity of zinc, and sometimes of copper, containing only a very small percentage of zinc, sometimes only just sufficient to make the copper draw with certainty. This latter material generally passes under the name of gilding metal, while the other, which is brass, is known under the name of cartridge metal, if it possesses the qualities required for the manufacture of cartridges.

In the course of my examination of this material I have frequently found that pieces of apparently the same metal, and under apparently the same conditions, taken from the same batch, but generally made from different sheets, would act very differently, some not being at all suitable for the purpose, and others being entirely up to standard. After examining cartridge metal, my attention was called by the manufacturers to the apparently unaccountable failures of punched and spun brass. These failures are so much taken as a matter of course that a certain percentage is regularly expected and allowed for in the contract specifications which are made for this material.

I shall, probably, at some future time have something further to say to the Society on this subject, but at present I merely wish to call their attention to the fact, that I do not consider the failure in any of these metals either necessary or without a cause.

We are too much in the habit of considering alloys as chemical compounds, and as being constant in their composition, in the same way that metals are. We consider that the metals are homogeneous, because we are in the habit of supposing that they do not give way except under well-defined circumstances, and we are not in the habit of examining very closely their physical condition after they fail. Alloys are not of constant composition, nor are they generally chemical combinations. It may be true that the materials composing the alloy are also in different conditions in different parts of the same piece. Probably some of you are aware what a delicate metal copper is, and what a very small percentage either of its own oxide or of other impurities will ruin it for commercial purposes. In the hundreds of samples of the ordinary brands of commercial copper which I have examined, I have not found, until within two years, since the perfection of certain of the processes of refining, copper that could even be called commercially pure. It generally contains, besides oxygen, small amounts of lead, zinc, cobalt and nickel. This is true to a great extent of the coppers produced in the great Ap-

palachian range, and to a less extent of those of Lake Superior, which have always been considered, until copper began to be produced from Arizona, as the best copper that the world has ever seen. This pure copper may be spoiled in the refining or in the melting by which brass is to be made.

The zinc contains many impurities. There are but two or three places, and those in this country, where a chemically pure zinc can be had.

We will, however, suppose that these two metals are pure when they are delivered at the works, and that it is desired to make brass of a fine quality. A workman, by carelessness in the management of the fire, may cause so much oxygen to be absorbed by the melted copper that the material is unfit for use before the zinc is added to it at all. After the copper has been melted the zinc is added. If this zinc is impure there is a still further deterioration of the metal. If the materials are left too long in the fire, or are not left there long enough, there will be a still further deterioration of the metal. If the brass is well made and is poured properly into the moulds, there will be a union of the copper with the zinc which will be partly chemical and partly mechanical. If this union is perfect, or nearly so, the brass resulting will be good.

We will suppose that up to this point everything has gone properly, and the brass, in slabs, is now ready to be delivered to the manufacturer. In order to get it into shape, it must be treated mechanically. To do this it must be made to pass between rolls, and brought to a certain width and thickness. In rolling it down it becomes brittle ; it must then be annealed. If it is annealed at the proper temperature, no injury is done to the metal. If the temperature is too low, the brass will be too hard when it goes under the rolls again, and may become deteriorated or even brittle from an unequal flow of the two metals of which it is composed. If the temperature is too high, it may be that the more volatile metal will begin to separate, so that, supposing the brass was good at the time it was delivered to the manufacturer, it may be injured first in the rolls, and second in the annealing. What may take place in the rolls is, first, producing the crystalline form which renders it brittle, and, second, if the pressure becomes very high, the absolute separation by cold flow of the two metals, which, as the rate of flow is different, will separate differently, and, consequently, the metal will be worthless. I have seen many tons of this material in the manufactories of the Naugatuck Valley, which is perfectly useless except to be re-melted.

If now the temperature in the annealing furnace is too high, the zinc will "start," as the manufacturers say, that is, it will commence to separate from the copper, and exactly the same phenomena, but produced in a different way, will take place ; that is to say, a flow of the metal has taken place, but it has been produced by heat, the result, in both cases, being in exactly the same condition, and the sheet metal made is worthless, except for purposes of manufacture.

In the manufacture of cartridges, this operation of annealing and of compressing the sheet metal takes place many times, and there are many opportunities for producing these results. I have not generally found that the material is wrongly treated in the hands of the cartridge metal manufacturers, for their work is usually done automatically. In almost every case where I have had the opportunity of tracing it, the defect has been found in the sheet metal delivered to the manufacturer. It had been either over-heated or over-compressed. The zinc had "started," and the material failed for this reason.

I have sampled as many as 500 000 cartridges in a factory by firing, and found that many could only be fired once, a few would fail on the second firing, still fewer would fail at the third, and that we could occasionally find in the same batch of metal, cartridges which would fire 150 times. In every case the failure was due to the same cause, and after an examination of hundreds of them, I became satisfied that this cause was either too great compression or too much heat ; this being true even in those samples which contained a minimum quantity of the volatile metal. It is even possible to produce a cold flow of the metal to such an extent that, with a sufficient pressure, the two metals may be entirely separated. The experiment has recently been made of putting together zinc and copper filings and pressing them under a powerful hydraulic press, and producing a metal which had every characteristic of brass. The inference is also that the two metals once together, apparently alloyed, may be separated by pressure; and this can be done. The same has been done for other alloys and for other metals in a finely divided state; nor should we be astonished at this, for it has been known for a long time that platinum sponge may be compressed to metallic platinum, and the experiment of making solid pieces from either sheets or powder of the more fusible metals, especially lead, has been repeated a great many times.

I have separated from many of these metals volumes of gas which

were five, sometimes ten, times the bulk of the metal. At some future time I hope to analyze this gas, and ascertain exactly what it is. This phenomena of the separation of gas always occurs in those metals which have been most compressed, and it would appear as if the brittleness was owing in a great many cases to the expansive force of the gas at high pressure, which is a force within the metal tending to help any force applied from without which would deteriorate it.

I, therefore, cannot admit that there are any peculiarities in these metals which must undergo great pressure, which cannot be remedied. The cause in every case can be ascertained, and the defect remedied, if the proper means are used. I devised a machine for this purpose, but, unfortunately, the necessity which led to the examination of these metals ceased to exist before the machine could be built.

I hope at some future time, in presenting to the Society the results of my study on the law of fatigue and refreshment of metals, to describe this machine, and I hope to show how it may be possible to ascertain, not only the defects in these metals, but the want of homogeneity as well as fatigue in metals which are used for structural purposes.

O. E. MICHAELIS.—I have listened with great interest to the remarks of Dr. Egleston, and I sincerely trust that he will soon be able to present to us the results of his novel investigations, which will, no doubt, throw much light upon a hitherto unsolved problem.

At the same time, I must say that the Doctor does not appear to appreciate the actual difficulty presented by the case under discussion. It is not sought to discover the cause of the failure of different batches of metal; but why a *certain* metal stood the severest, the most searching tests successfully, and thereafter failed in the gun. The cartridge metal described underwent the various operations of drawing, heading and tapering, unannealed, and gave no sign of weakness; its strain-diagrams are the counterparts of those given by accepted metal; its behavior was satisfactory in the eprouvette; yet it could not be used safely for the manufacture of cartridges. Of course, there must be a reason for this failure, but it was not discoverable under the most exhaustive tests that our experience led us to institute, and the presentation of this fact is the main object of the paper.